VIII. Installation and Integration into STAR

This section describes the Interfaces between EMC and the rest of STAR, including the mechanical integration and the installation.

VIII.1 Installation

VIII.1.1 Overview of Module installation

As described previously, the EMC modules are supported inside the STAR magnet on pairs of rails. This method was chosen because the EMC is a staged detector and parts of it must be installed over a period of years with the TPC already in place. The rails are supported by a system of support segments sometimes referred to as hangers. These supports fit between the coils of the conventional magnet so that the rail and module loads are transferred to the magnet backleg steel. There are 9 rings of supports, 8 of one type and one type for the center, which supports the rails for two modules. There are two modules end to end to span the length of the barrel, and 60 in phi for a total of 120 modules. Each ring is made of 30 segments, the so-called singles, which support one module and the triples, which support 3. This breakup into 1 and 3 was necessary to make the EMC boundaries match the TPC boundaries after the TPC design was rotated.

The basic approach to module installation is to slide a module off a set of rails in an installation fixture and onto the rails in the magnet. The bundles of fiber optics must be pulled out between the magnet coils in a continuous manner as the module slides into the STAR magnet.

The installation fixture will be supported partially be bolting to the STAR magnet, and partially by the building crane during installation of a module. The fixture is designed with a series of lifting holes related to the module center of mass so that it can be aligned easily when lifting and attaching to the magnet. A second attachment to the crane, a come-along, permits fine adjustment and also compensates for the change in center of gravity as a module is slid off the fixture and into the magnet.

This basic approach of a fixture with holes over the C.G. for each angle, and a second support for fine adjustment was used to assemble the STAR magnet backlegs. It allowed adjustment of a fraction of a degree in angle while hanging before any attachments to the magnet were made.

This method of installation was chosen because it is simple, economical, and quick to build. Also, there is a problem with using floor-supported installation fixtures because of the rails on the floor for the pole piece supports.

Fiber guides are in place on the rail supports between the coils of the STAR magnet. These protect the fibers by providing a 4 inch radius of curvature for the fiber bundles, and they also guide the fibers into the channel between backleg iron bars.

At the beginning of installation, all the pre-assembled bundles of fibers must be attached to the module. These are laid into a channel along the top of the module, to the side of the spacer plate and carriage. They all extend past the eta=0 end of the module, so that at that point, all the fibers must be in the channel. Ropes are pre-inserted between coils before installation, and these are tied to the appropriate fiber bundles. The ropes are then pulled as the module is inserted. When the module is fully inserted, the fibers are plugged into the connectors on the sides of the PMT boxes.

VIII.1.2 Analysis of the segments and rails

A Finite Element Analysis (FEA) was performed on the support segments and the rails. The support segments were analyzed in the 12 o'clock and 3 o'clock positions. A .25g seismic load was considered for both of these load conditions. The maximum stress in the segments was 6,200psi. The segments were fabricated from 6061T6 aluminum that has a yield stress of 36,000psi so there is nearly a 6 to 1 factor of safety. The deflection of the segments was negligible.

Similarly, a FEA model was used to examine the rails. The rails were loaded in the 12 and 3 o'clock positions. The load from the module was applied at the estimated center of gravity of the module and between the support segments to simulate module insertion which is the worst case condition. The maximum stress in the rail was 6900psi, which closely matches the 7,500 psi stress from hand calculations.

Rail twist in the 3 o'clock position is a concern since this could result in phi contact between modules during insertion. The calculated twist with the FEA model was .62 degrees and .58 degrees from hand calculations. A twist of .62 degrees would result in modules contacting, assuming that there is only a .5mm gap between modules.

VIII.1.3 ϕ Gap analysis

The cover to cover phi gap between modules is determined by the following factors:

1. Module construction tolerances
2. Module deflection
3. Rail alignment tolerances
4. Rail deflection

The worst position in the detector is in the 3 o'clock location where phi deflections of the module and rail will be the worst. Rail deflections address only the twist and sag in the rail when the module is completely installed. The maximum rail deflections will actually occur during installation. This deflection / twist has been measured with a dummy EMC module on a real set of rails and rail supports. It is smaller than expected. It was believed that the twist of the rails would be so large that designing to this criteria would result in an unacceptably large phi gap. In order to overcome this the plan was that the modules would be installed from the top of the detector down so that no modules would ever be below the one being installed, thereby avoiding interference. An option we have which is not currently deemed necessary is to add additional carriages to the modules near 3 and 9 o’clock to greatly reduce the rail twist during installation

Currently a cover to cover gap of 5.6 mm is anticipated which is a 2.8 mm half gap. This gap is determined by:

1. Module construction tolerances of 1.54mm
2. A module deflection of .5mm based upon measurements of a prototype constructed at Argonne.
3. .5mm is assigned to the alignment of the rails. This is occurring currently so it is to early to determine if the .5mm alignment tolerance is being achieved. An analysis of initial data, however, indicates that this tolerance will be met.

4. .25mm has been assigned to the deflection of the rails with the modules completely installed. This is based upon calculations described above.

VIII.1.4 Rail Alignment

On the basis of the measurement of 10 installed and aligned rails, none of the rails have any measurable twist. All of the rails have variation along their length in radius of up to .020" which is due to the deflection of the backleg iron. We did not shim this out because radial variation at this level results in less than .1mm phi variation. In phi we have been aligning the two ends of the rail and then locking them into place. We then take measurements along the length of the rail, which show variation of up to .015". We feel that this is due to the rail not being straight. We make the adjustments that we can but it is very difficult to get all five points to line up. We have accepted .012" variation in phi along the length of the rail. Since there is no measurable twist, this is acceptable.

VIII.1.5 Installation Test

An installation test has been prepared at ANL to test the procedure of installing a module, and to confirm calculated rail twists and clearances. These studies try out various facets of installation such as transferring the module to the rails in a fake magnet from a fake installation fixture, pulling the fiber bundles up between fake coils, and examining deflections. The installation will be performed at angles of 6 o'clock, 9 o'clock, and 12 o'clock.

This test uses real support segments, real rails, real fiber guides, and a mechanical prototype with dummy scintillator and reject fibers.

VIII.2 Integration

VIII.2.1 Overview

The mechanical integration involves many facets. The Integration Group at LBL has, in cooperation with each sub-system, defined spatial integration envelopes for each sub-system such as EMC. These are subject to review and change control. There are issues of providing services such as electrical power, detector gas for MSD, cooling gas for SMD, cooling water for Phototubes. These issues are described in chapters on conventional systems or the individual EMC sub-systems. There has been extensive iteration in defining EMC space on the platforms in the racks for Low voltage power, and VME crates for Data collection and Trigger and controls. What we describe below has largely to do with fitting parts of EMC into the available envelope, and establishing connections.

VIII.2.2 Integration of PMT boxes

The PMT boxes mount on the STAR backleg iron bars, and are separate from the EMC electronics crates.

The PMT boxes provide:

- Light tight environment for phototubes and fiber decoding.
- Mounting support structure for shielded PMT assemblies
- Temperature control
- Interface between fiber bundles and fiber decoding.
- Electrical shielding

Each box has 1680 fibers from the calorimeter towers and 160 fibers from the pre-shower upgrade coming in. There are 80 cables of RG174 leaving each box for the tower phototubes. There are a few flat cables to provide Low Voltage and control signals. In addition, there are two water tubes of 3/8 in copper for cooling.

Due to the constraints of the STAR magnet, there are 3 different areas with different size constraints on the PMT boxes. We have chosen to have only 2 different kinds of boxes for reasons of mass production economy.

The constraint on top of the magnet is that only 9 inches is available to clear the door when the detector rolls in. This means that electronics crates on 9 backlegs will have to be dismounted to roll the detector in and out. However, the calibration would be lost if the fiber optics was disconnected, and there would be danger of damage as well. Thus, the top boxes will be 9 inches high. The electronics crates can be mounted in such a way to allow a length of 90 inches for the top PMT boxes. The boxes are 22.5 inches wide, the same as the backleg iron, to allow access to fibers and connectors during installation, and to protect the fibers coming out the sides of the box at a steep angle.

The constraint at the bottom of the magnet is most severe in length. The cradle for the magnet restricts the space to 66 inches and the integration of the magnet hydraulics and power further restrains the box length to 57 inches.

There are other constraints at the sides of the magnet below the water hoses and power cables. Here the length is not limited, but the width of the box is limited and the radial height is limited. The boxes for the top of the magnet can be made to work here by offsetting them from the center of the backleg bar.

The EMC electronics crates on the magnet backleg iron are the size of 9U VME crates, but of 8 slot width. Thus, they can lie flat on the magnet backleg, consistent with the door clearance for rolling in STAR. The signal are connected through mass connectors,
So that crates can be removed for servicing.

VIII.2.3 Cables and Tubing

EMC Cable list

ITEM	QUAN.	SIZE	PWR	SIG	TYPE	SYS
EMC Detector/boxes to Crates						
EMC barrel PMT						
CCW power and controls	4800	0.1 x 0.75 in	x	x	flat	CCW
PMT signals	4800	0.1 dia.		x	coax	CCW
LED power/control	840	0.1 x 0.75	x	x	flat	LED
box Temp Probe	120	0.1 x 0.75	x	x	flat	Conv
PMT box water pipe	120	0.38 dia			pipe	PMT

ITEM	QUAN.	SIZE	PWR	SIG	TYPE	SYS
EMC Barrel SMD						
FEE to RDO :						
SMD signal ,clk, temp.	120	0.1 x 1.4		x	flat/twist/shield	
SMD power	120	0.375 dia		x	multi	
SMD gas tube	240	0.25 dia			tube	SMD-Conv
SMD cooling gas tube	240	0.25 dia			tube	SMD-Conv
SMD to Platform:						
SMD HV	120	0.25 dia		x	RG59	
SMD FEE to Platform:						
SMD Calibration	120	0.3		x	2 two pair	
SMD RDO to Platform:						
SMD slow control/HDLC	8	0.3		x	multi	HDLC
SMD trig / clk	8	0.3		x	multi	Trg/Clk
AC Power	8					
SMD RDO to DAQ						
Gigalink Fiber	8	0.2			fiber	
EMC Barrel Crate to Crate						
Trg-Clk fanout	1	0.1 x 0.8		x	flat	PMT-elec
Slow control/HDLC	2	0.3 dia		x	multi	HDLC
SMD gas pipe	4	1.25 dia			pipe	gas
SMD cooling gas pipe	4	0.5 dia			pipe	gas
SMD gas flow meas	120					
PMT box water pipe	4	1.25 dia			pipe	PMT
LED etc serial line	4	0.25 dia		x	multi	LED

ITEM	QUAN.	SIZE	PWR	SIG	TYPE	SYS
EMC Barrel Crates to Platform						
Crate power 120 V	30	0.3 dia		x	multi	AC
PMT data	30	0.2 dia		x	fiber	MPX
PMT trigger	300	0.1 x 0.8		x	flat	trg
Trg-Clk fanout	1	0.1 x 0.8		x	flat	
Slow cnt/HDLC	2	0.3 dia		x	multi	HDLC
SMD gas pipe	4	1.25 dia			pipe	gas
SMD cooling gas pipe	4	0.5 dia			pipe	gas
LED etc serial line	4	0.25 dia		x	multi	LED
Slow cnt/HDLC	2	0.3 dia		x	multi	HDLC
EMC Barrel Platform to Counting House						
Optical PMT data	1	0.2 dia		x	fiber	DAQ
Optical spare	2	0.2 dia		x	fiber	DAQ

VIII.3 Interfaces

INTERFACE to DAQ

Data format into DAQ:
64 byte header, first 16 bytes in standard STAR format. Included is token, trigger command word, DAQ command word, and switch to indicate sparsification
Each group of 160 PMT words is preceded by 4 words of header.
Included is token, crate number, and local counter.
The SMD readout has internal headers as in the SVT system which also match the standard format for DAQ.

Event size with No sparsification and no addresses is 10 kB for Barrel Towers, and 50 kB for SMD. With sparsification and the addition of addresses in pp events this may be reduced to less than 1 kB for Barrel Towers and 2 kB for SMD. Sparsification will be done in DAQ.
Event rates into DAQ for events utilizing TPC cannot be more than
100 Hz and will be kept to 60 Hz to accommodate livetime req.

Event Rates of EMC + SMD only will be less than 1000 Hz.
These are small events used for setting up triggers, etc.

EMC data collector must stop pushing upon DAQ busy.

EMC collector must push data upon Level 2 accept.

The data path into DAQ is 1 gigalink from EMC towers for baseline running
(upgrade to 1 for each of 24 TPC crates for High Lum pp)

The data path into DAQ is 8 gigalinks for SMD (stays fixed at 8 for high Lum pp)

INTERFACE TO TRIGGER

EMC input to Level 0:
sends to Level 0: 3600 bits to first layer of DSM boards
(special grouping of bits)

Level 0 Latency:	Tics
Cable	2.1
Integrator	0.5
FADC	4
FPGA s	1
Cable	0.4
total	8

At least 3 more layers of DSM boards are needed for triggers utilizing EMC.

EMC can utilize Lvl 0 trigger up to 2 u sec after crossing (programmable)

EMC will respond to event Abort (by clearing token from collector memory) so that the event is not transmitted to a higher level.

SMD sends nothing to LvL 0 in baseline running

EMC does not require LvL 1 or LvL 2 triggers for baseline running, only a level 1 accept at level 1 time.

For High Luminosity running, upgrades to trigger will be required to accommodate thresholds similar to those in baseline running but with a factor of 20 more luminosity and better live time.

Example:

For the High Lum pp upgrade, SMD will send 240 bits to be utilized either in Level 0 or Level 1 or very early Level 2 for correlation with EMC in geometric way.

Scalers:

EMC requires scalers of Luminosity monitor, and TCU (Trigger Control Unit) actions with tagging of all implemented deadtimes and pre-scales. Different pre-scales will be required at different EMC thresholds. These may be implemented upon EMC LVL 0 or upon TCU output.

The Spin Program requires that multiple EMC Luminosity outputs be scaled with both Polarization tagging and dead time tagging, and that TCU actions also be scaled with these tags.

INTERFACE TO ONLINE

EMC communicates to slow control functions through Online.

EMC calibration data bases must be maintained with a database system within online and made available to DAQ, (and LVL 2 when it exists)

EMC HV data sets must be maintained for Heavy Ion and for pp.

EMC requires updating histograms and scaler displays from online, such as SMD pulse height/noise distributions.

SLOW CONTROLS FUNCTIONS

Requirement:

There are slow controls inputs to EMC for the following functions:

- HV settings to Cockroft-Walton PMT bases
- Tower Calibration
- LED pulse control (trigger setup, timing, pattern)
- Charge injection to PMT electronics
- Monte-Carlo event downloading
- Trigger threshold programming on EMC cards
- Initialization of some circuits
- Read temperatures of PMT and electronics
- Monitor crate voltages
- Trigger Mapping programming
- Testing of Tower card data path
- Testing of Tower card trigger and LVL 0 interface
- Testing of EMC data collector
- Begin run functions
- Buffer clearing
- Monte-Carlo event downloading to Data Collector
- Bad channel list download to EMC Trigger
- Run Header information download to Data Collector
- Bad channel list downloading for Level-1 or 2 (if this option is exercised)

- SMD slow controls:

    HV control and Monitor
    HV current monitor
    Gas system control and Monitor
    Control cooling gas for SMD
    electronics temperature monitor
    electronics power monitor
    Crate power on/off
    Calibration Pulser Masking and Level Control
    Test data load and read

INTERFACE TO OFFLINE

EMC must supply

information on event format,

calibration databases (which have version numbers)

algorithms for energy in EMC towers,

algorithms for SMD shower fitting,

INTERFACE TO GAS

EMC requires ArCo2 for SMD operation.

EMC requires compressed air for cooling SMD electronics on the module.

INTERFACE TO WATER

EMC requires Water to cool the phototube boxes, in addition to the standard cooling of crates on the platform. The requirement is less than 30 GPM. at 60 to 65 Dec F.

INTERFACE TO POWER

EMC requires power for

EMC crates on the magnet, less than 15 kW, supplied by 120 V AC

SMD electronics on the magnet, less than 4 kW, supplied by 120 V AC

Slow controls functions, 5 and 12 V, less than 2 kW

Cooling fans on crates and in Phototube boxes, less than 3 kW

VME crates on the Platform, 4 Standard STAR crates

INTERFACE TO BUILDING TEMPERATURE CONTROL

EMC will dissipate the heat form EMC crates and SMD electronics into the building. This will be less than 25 kW.